PART 1

INTRODUCTION AND ANALYSIS OF SECONDARY DATA

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ACRONYMS

DISCO	=	Distribution Company
GDP	=	Gross Domestic Product
GENCO	=	Generation Company
GOP	=	Government of Pakistan
GWH	=	Giga Watt Hour
IPP	=	Independent Power Producer
IPP	=	Institute of Public Policy
KESC	=	Karachi Electric Supply Corporation
K-PK	=	Khyber-Pakhtunkhwa
Kwh	=	Kilowatt Hour
LDC	=	Least Developed Country
LESCO	=	Lahore Electric Supply Company
MEPCO	=	Multan Electric Power Company
MOF	=	Ministry of Finance
MW	=	Mega Watt
NEPRA	=	National Electric Power Regulatory Authority
NTDC	=	National Transmission and Despatch Company
OLS	=	Ordinary Least Squares
PEPCO	=	Pakistan Electric Power Company
PES	=	Pakistan Economic Survey
PESCO	=	Peshawer Electric Supply Company
SBP	=	State Bank of Pakistan
TV	=	Television
UK	=	United Kingdom
USA	=	United States of America
USAID	=	United States Agency for International Development
WAPDA	=	Water and Power Development Authority
WDI	=	World Development Indicators
WTP	=	Willingness to Pay

CHAPTER 1
INTRODUCTION

The widespread and growing phenomenon of power loadshedding has emerged as one of the principal supply-side constraints to growth of the economy of the Pakistan. Not only has this led to significant losses of output, employment and exports but also during periods of high outages there have been large-scale protests, particularly in Punjab and K-PK. The magnitude of this problem and the urgency to resolve it has motivated **Advance Engineering Associates International, Inc.,** to commission the institute of Public Policy, Beaconhouse National University, Lahore to undertake the **Study on the Economic Costs of Power Loadshedding to Pakistan.**

1.1 STATEMENT OF WORK

The assessment of economic cost of load shedding to Pakistan's economy sets out the following tasks:

- Provide an approach and methodology for quantifying cost of load shedding to Pakistan's economy;
- Explore GDP contribution of each relevant sector of the economy including commercial, domestic, industrial and agricultural.
- Determine consumption of electricity of each of these sectors
- Determine direct cost of load shedding in each of these sectors (for example loss in business due to unavailability of electricity in the industrial sector)
- Determine national cost of load shedding using secondary data, primary data, and in-depth interviews with representative stakeholders including but not limited to electricity consumers in domestic, commercial, industrial, and agriculture sectors;
- Determine economic costs of using alternative sources of electricity, if possible in each sector
- Determine costs associated with alternative supply of electricity primarily through captive generation on gas and generation on oil
- Provide policy implications, conclusions, and recommendations as well as explore economic load dispatch to assist in drafting policy to optimize efficient use of electricity and minimize costs associated with load shedding and exploring other viable options.
- This will involve the following:
- Undertake Study on Economic cost of Load Shedding to Pakistan
- Determine, collect and analyze secondary data

- Conduct cost of outage survey
- Review and analyze the data generated by survey
- Carry out interviews of leadership and management of WAPDA, PEPCO, DISCOs, GENCOs, and NTDC
- Carry out interviews with other stakeholders in domestic, commercial, industrial, and agriculture sectors
- Have Focus Group Discussions if needed
- Provide an appropriate approach and methodology for quantifying cost of load shedding to Pakistan's economy
- Analyze and determine national cost of load shedding
- Provide policy implications for minimizing the impact of load shedding
- Make presentations to USAID and GOP officials
- Prepare draft and final report for the study

1.2 METHODOLOGY

The approach to quantifying the cost of power outages has been developed in Pasha, Ghaus and Malik [1989 and 1990] based on a big study sponsored by USAID in 1987. This methodology has been considered as pioneering in character and is extensively used internationally.

The proposed sample sizes of different types of power consumers are given below:

Large-Scale Industry	500
Small-Scale Industry	500
Agriculture	250
Commercial	250
Domestic	500

The proposed locations of the survey are as follows:
Sindh: Karachi, Hyderabad, Sukkur

Punjab: Lahore, Faisalabad, Sialkot, Gujranwala, Multan Rawalpindi

Khyber-Pakhtunkhwa : Peshawer, Mardan, Abbottabad

Balochistan : Quetta, Turbat

Islamabad

The survey will be sequenced and to the extent possible local surveyors will be recruited and trained.

It is expected that the study will be completed in nine months.

1.3 THE OUTPUTS

The report will consist of the following parts:

Part 1: Introduction and analysis of secondary data

Part 2: Costs of Loadshedding to small scale industry

Part 3: Costs of Loadshedding to commercial/service establishments

Part 4: Costs of Loadshedding to Domestic consumers

Part 5: Costs of Loadshedding to Agriculture

CHAPTER 2
THE POWER SECTOR OF PAKISTAN

The objective of this chapter is to highlight the key trends and facts about the economy of Pakistan and the power sector respectively. This will highlight the contribution of different factors to the emergence of high levels of loadshedding in the country and the impact thereof on economic growth.

The Chapter is organized as follows: Section1 contrasts the growth rate of the economy prior to and after the commencement of significant loadshedding in 2007-08. Section 2 presents an inter-country comparison of access to electricity in order to highlight the relative level of development of the power sector of Pakistan. Section 3 identifies the long term trends in the sector, while Section 4 gives the growth in and pattern of electricity consumption. Finally, Section 5 quantifies the supply gap in the provision of power and the implied level of loadshedding.

2.1 STRUCTURE AND GROWTH OF THE ECONOMY

The economy exhibited considerable dynamism during the earlier years of the last decade, especially from 2002-03 to 2006-07. But from 2007-08 onwards the growth rate has declined sharply up to 2010-11 from almost 6% annually to below 3% as shown in Table 2.1. In 2011-12 there has been a modest recovery.

The plummeting of the GDP growth rate coincides with the emergence of loadshedding. But while this supply-side factor has constrained growth, it is not the only factor. There was a major financial crisis globally in 2008 and Pakistan's exports were adversely affected. Subsequently, with the intensification of war on terror, security conditions have deteriorated and heightened perceptions of risk have led to a steep fall in private investment, which has virtually hit an all time low level. On the top of all this, the devastating floods of 2010 led to large losses of output, especially in agriculture. Overall, it is clear that in the absence of power load shedding the economy would not have achieved 6% growth, but in the presence of problem the fall in growth rate has been greater.

Table 2.1 shows that the sharpest decline in the growth rate has been in the industrial sector from 7 to 2.5 percent. Industry is a major consumer of electricity. The only sector which has shown high growth is the government, especially in current expenditure.

Table 2.1 Growth Rate of Different Sectors and of the GDP (Rs in Billion at 1999-2000 prices)			
	2000-01	**2007-08**	**2011-12**
Agriculture	903.5	1148.9 (3.5)*	1269.5 (2.5)
Industry	865.2	1387.1 (7.0)	1531.2 (2.5)
Commercial/Services	1638.2	2526.4 (6.4)	2829.0 (2.9)
Government	225.1	320.6 (5.2)	398.9 (5.6)
GDP(fc)	3632.0	5383.0 (5.8)	6028.6 (2.9)

*Figures in brackets are annual growth rates from 2000-01 to 2007-08 and from 2007-08 to 2011-12 respectively
Source: PES

The contribution of different sectors to the GDP is indicated in Table 2.2. The process of structural change which was observed in the period of high growth has been largely arrested as shown in Table 2.2. Industry now accounts for about one-fourth of the economy, while the agricultural sector contributes just over one-fifth to the GDP. The largest part of the economy is accounted for by commercial/services activities, especially in transport and communications and wholesale and retail trade. A comparison of the sectoral contribution to the GDP with the share in power consumption is made later.

Table 2.2
Contribution of Different Sectors to GDP
(at constant prices of 1999-2000)

(%)

	2000-01	**2007-08**	**2011-12**
Agriculture	**24.9**	**21.3**	**21.1**
Crops	11.8	9.5	8.8
Livestock	11.9	11.2	11.6
Other	1.2	0.6	0.6
Industry	**23.8**	**25.8**	**25.4**
Mining	2.4	2.6	2.4
Large-Scale Manufacturing	10.3	13.4	11.9
Small-Scale Manufacturing**	5.4	5.8	6.7
Electricity and Gas	2.9	1.6	2.2
Construction	2.4	2.4	2.2
Commercial/Services	**45.1**	**47.0**	**46.9**
Transport and Communications	11.6	10.0	9.6
Whole sale & Retail Trade	17.9	17.4	17.1
Finance & Insurance	3.1	6.3	4.8
Ownership of Dwellings	3.2	2.7	2.7
Social and Personal Services	9.3	10.6	12.6
Government	**6.2**	**6.0**	**6.6**
Public Admin & Defence	6.2	6.0	6.7
Total GDP	**100.0**	**100.0**	**100.0**

Source: PES, MOF

2.2 INTERNATIONAL COMPARISONS

A comparison is made of key indicators of the power sector in different Asian countries, both in South Asia and East Asia. There is apparently a strong correlation between per capita electricity consumption and the level of development. Pakistan has both relatively low energy consumption and per capita income as compared to India and Sri Lanka in South Asia and virtually all East Asian countries.

The somewhat early stage of development of the power sector in Pakistan is also indicated by the low share of population with access to electricity at 62% as compared to 66% in India, 77% in Sri Lanka, 90% in Philippines and 99% in Malaysia.

It is also observed that the energy intensity in production increases as development takes place. This is confirmed by Table 2.3 which shows that the GDP per kwh is $ 2.3 in China as compared to $ 11.5 in an LDC like Nepal. Pakistan is at an intermediate level at $ 5.3.

Table 2.3
Indicators Of Electricity Consumption In Selected Countries
(2009)

	Per capita GDP, PPP (at constant 2005 prices)	% of Population with Access to Electricity	Electricity Consumption per Capita (kwh)	GDP per kwh ($)
Country				
Bangladesh	1419	41.0	251.6	5.64
China	6206	99.4	2631.4	2.36
India	2813	**66.3**	570.9	4.93
Indonesia	3696	64.5	590.2	6.26
Malaysia	12526	99.4	3613.5	3.47
Nepal	1048	43.6	91.0	11.52
Pakistan	2357	62.4	449.3	5.25
Philipines	3364	89.7	593.5	5.67
Sri Lanka	4301	76.6	412.9	10.42
Thailand	7160	99.3	2044.8	3.50
Vietnam	2721	97.6	917.6	2.96

Source: World Bank, WDI

The level and sources of electricity generation and magnitude of system losses (in transmission and distribution) are presented in Table 2.4. There is a wide variation among countries in sources of power. Countries which rely most on coal include China, India and Indonesia. Hydroelectricity is the dominant source in Nepal, which given its location in proximity to the Himalayas has enormous untapped potential for hydro-electricity, like Pakistan.

Table 2.4
Level and Sources of Electricity Generation and System Losses in Selected Countries (2009)

Country	Per Capita Electricity Production (kwh)	Sources of Electricity					System Losses (%)
		Coal (1)	Hydro (2)	Gas (3)	Nuclear (4)	Oil (5)	
Bangladesh	257.6	1.7	4.1	89.4	0.0	4.8	2.3
China	2776.0	78.8	16.7	1.4	1.9	0.4	5.2
India	744.7	68.6	11.9	12.4	2.1	2.9	23.3
Indonesia	654.9	41.8	7.3	22.1	0.0	22.8	9.9
Malaysia	3759.7	30.9	6.3	60.7	0.0	2.0	3.9
Nepal	106.1	0.0	99.6	0.0	0.0	0.4	14.2
Pakistan	559.2	0.1	29.4	29.4	3.0	38.0	19.7
Philipines	675.3	26.6	15.8	32.1	0.0	8.7	12.1
Sri Lanka	483.3	0.0	39.5	0.0	0.0	60.3	14.6
Thailand	2159.9	19.9	4.8	70.7	0.0	0.5	5.3
Vietnam	967.3	18.0	36.0	43.4	0.0	2.5	5.1

Source: World Bank,WDI.

Gas is the principal source in Bangladesh, Malaysia, Philippines, Thailand, and Vietnam until recently, Pakistan. Thermal power has emerged as a major source in Sri Lanka and Pakistan. The pattern of sources of electricity of Pakistan exposes the country to two major risks. Dependence on gas at a time when reserves are depleting implies severe constraints in the medium to long run and the need to switch to other sources. The growing reliance on thermal power exposes the economy to 'oil price shocks'.

Turning to system losses, a key indicator of efficiency, both India and Pakistan do poorly at 23% and 20% respectively. Even an LDC like Bangladesh performs much better with only marginal losses. Similarly, other countries like China, Malaysia, Thailand and Vietnam have been successful in containing system losses.

2.3 LONG-TERM TRENDS IN POWER SECTOR

The growth in installed capacity and generation of electricity in Pakistan is presented in Table 2.5 since 1970-71. The former has been more than doubling every decade up to 2000-01, with annual growth rate over 7%. It is only during the last decade that the rate of expansion in capacity has substantially slowed down to 3% per annum. In the initial years of the decade there was significant excess capacity, due to the hump in investment by the IPPs in the mid-to late-90s. But adequate provisions were not made to cater for the future growth in demand.

The growth in electricity generation was rapid in the 70s and 80s. in particular, the commissioning of the Tarbela Dam in the early 80s enabled a quantum jump in supplies at low cost. Consequently, electricity generation grew annually by almost 10%. During the 90s as the growth rate of the economy slowed down, demand for electricity was not so buoyant and the rate of increase annually in power generation declined to 5%. During the last decade, this has fallen further to only 3%.

An index of capacity utilization[1] is constructed in Table 2.5. The rate of capacity utilization exceeded 100% by 1990-91 and the loadshedding which occurred in a significant way in the mid-to-late-80s can be attributed to a shortage of capacity. It was during this period that the first study in Pakistan on costs of loadshedding was undertaken by Pasha, Ghaus and Malik [1989], with support from USAID. As opposed to this, the upsurge in loadshedding once again since 2007-08 can be attributed primarily to a lack of full capacity utilization arising from lack of adequate maintenance of older plants and liquidity problems due to the ballooning of circular debt.

2.4 GROWTH AND PATTERN OF ELECTRICITY CONSUMPTION

The growth in electricity consumption by type of consumer during the last decade is presented in Table 2.6. The analysis is broken up into two sub-periods, the years prior to commencement of significant loadshedding in 2007-08 and the years thereafter. In the latter period, the overall growth rate in power consumption has fallen to 2% only due to progressively higher levels of loadshedding. A comparison of Table 2.5 with Table 2.6 also indicates that system losses in transmission and distribution were 29% in 2000-01 and 19% in 2010-11.

Table 2.5
Long-Term Trend in Capacity and Generation in Pakistan of Electricity 1970-71 to 2010-11*

	Installed Capacity (MW)	Annual Growth Rate (%)	Electricity Generation (GWH)	Annual Growth Rate (%)	Index of Capacity Utilisation (%)
1970-71	1862		7202		81
1980-81	4105	8.2	16062	8.4	82
1990-91	8356	7.4	41042	9.8	102
2000-01	17498	7.7	68117	5.2	81
2010-11	22447	2.5	94653	3.3	88

*Figures for 2011-12 were not finalised at the time of preparation of this report.
Source: Handbook of Statistics, SBP, Pakistan Economic Survey, MOF, GOP

[1] 300 days operation with 16 hours daily.

Table 2.6 Growth in Electricity Consumption from 2000-01 to 2010-11 (GWH)						
	Domestic	**Industrial**	**Commercial**	**Agricultural**	**Others***	**Total**
2000-01	22765	14349	1774	4924	3773	48585
2007-08	33704	20129	5572	8472	4923	73400
2010-11	35885	21207	5782	8971	5254	77099
Growth Rate (%)						
2000-01 to 2007-08	5.8	5.4	10.5	8.1	6.7	6.1
2007-08 to 2010-11	2.1	0.8	0.5	1.9	2.2	1.6
2001-01 to 2010-11	4.7	4.0	7.6	6.2	3.4	4.7

* mostly government, street lights and traction
Source: PES

The fastest growth in consumption during the last decade is observed in the case of commercial consumers followed by agriculture. Consumption by industrial consumers has grown less rapidly at 4% per annum and by less than 1% since 2007-08. The power shortage is clearly a major factor limiting industrial growth currently.

Table 2.7 highlights the relationship between growth in sectoral value added and growth in electricity consumption. The rise in the rate of response of production to an increase in supply of electricity after 2007-08 indicates that efforts are being made to increase energy efficiency and invest in self-generation of power to at least partially sustain levels of production.

Table 2.7 Growth Rate of Sectoral Value Added and Electricity Consumption (%)						
	2000-01 to 2007-08			**2007-08 to 2010-11**		
	Growth Rate of Value Added	Growth Rate of Electricity of Consumption	Elasticity*	Growth Rate of Value Added	Growth Rate of Electricity Consumption	Elasticity*
Agriculture	3.5	8.1	0.432	2.3	1.9	1.211
Industry	7.0	5.4	1.296	2.2	0.8	2.750
Commercial	6.4	10.	0.610	2.4	0.5	4.800
Government	5.8	6.7	0.866	6.6	1.9	3.473

Source: Derived
*Growth rate of value divided by growth rate of electricity consumption.

The share of different types of consumers in power consumption is given in Table 2.8. The largest category continues to be domestic consumers, with a share of almost 47% in 2010-11. The next group is industrial consumers whose share has fallen from about 30% in 2000-01 to 28% in 2011-12. As such, these two groups of consumers account for almost three-fourths of the consumption of electricity in the country. The remainder is shared between agricultural consumers (12%), commercial consumers (7%) and others (7%).

The impact of load shedding in recent years is clearly demonstrated in Table 2.9 by the fall in energy consumption per consumer after 2007-08 in the case of all consumers, with the largest decline in the case of industrial consumers of over 8%.

Table 2.8
Share of Different Types of Consumers in Electricity Consumption

(%)

	Domestic	**Industrial**	**Commercial**	**Agricultural**	**Others***	**Total**
Year						
2000-01	46.9	29.5	5.7	10.1	7.8	100.0
2007-08	45.9	28.2	7.6	11.5	6.7	100.0
2010-11	46.4	27.5	7.5	11.6	6.8	100.0

Source: NEPRA, State of Industry Reports

Table 2.9
Growth in Electricity Consumption per Consumer

(%)

	Growth rate (%)	
Type	**2000-01 to 2007-08**	**2007-08 to 2010-11**
Domestic	1.7	-6.0
Industrial	-1.2	-8.1
Commercial	21.8	-3.9
Agricultural	-0.7	-7.2
Others	20.6	-7.5
Total	**0.5**	**-6.6**

Source: NEPRA, State of Industry Report

A comparison is also made for each sector between the share in the GDP and the share in electricity consumption in table 2.10. The ratio in the table is a measure of the electricity-intensity of a sector. This is the highest for industry followed by government. The least electricity-intensive sector is commerce.

Table 2.10 Comparison by Sector of share in GDP and share in Electricity Consumption* (%)			
	2011		
Sector	Share in GDP (1)	Share electricity consumption* (2)	Ratio (2)÷(1)
Industry	25.4	51.4	2.02
Commerce	46.7	14.0	0.30
Agriculture	21.2	21.7	1.02
other**	6.7	12.8	1.91

* excluding domestic consumers

** mostly government
Source: derived

2.5 THE SUPPLY GAP

The surplus/deficit between demand and supply during system peak hours for NTDC and KESC combined is given Table 2.11. The supply gap was 1912 MW in 2007 which has risen to 5656 MW, equivalent to 27 % of demand[2]. It is important to note that in 2010-11 NEPRA reports the generation capability as only 69% of the installed capacity. The former has remained, more or less, unchanged since 2007.

Table 2.11
Surplus/Deficit in Demand and Supply during System* Peak Hours

	Generation Capacity	Demand	Supply-Gap	%
2007	15575	17487	-1912	11
2008	14707	19281	-4574	24
2009	16050	20304	-4254	26
2010	15144	21029	-5885	28
2011	15430	21086	-5656	27

* NTDC and KESC combined
Source: NEPRA, State of Industry Report

According to NEPRA, the highest incidence of outages regionally is in the area served by MEPCO, PESCO and LESCO[3]. The least outages are in IESCO. Most areas of Punjab and Khyper-Pakhtunkhwa are more vulnerable to load shedding.

[2] This gap is based on little or no growth in demand in 2011.
[3] The distribution companies in Multan, Peshawar and Lahore designated areas.

CHAPTER 3
METHODOLOGY FOR QUANTIFICATION OF COST OF LOADSHEDDING

Various approaches have been developed in the literature for quantification of the cost incurred by different types of consumers as a result of power outages. These approaches vary greatly in terms of data requirements and level of complexity. The Chapter starts with the simple value added approach and ends with the full-blown survey based and contingent valuation approaches.

3.1. THE SIMPLE VALUE ADDED APPROACH

A relatively high estimate of the cost of loadshedding is as follows:

V_i = Value added by sector i in absence of Loadshedding

E_i = Electricity consumption in the absence of loadshedding

Then the cost C_i, of loadshedding is give by

$$C_i = \frac{V_i}{E_i} l_i \quad \text{...(1)}$$

Where l_i is the quantum of electricity not supplied due to outages. Summing across sectors, the total cost of loadshedding is given by

$$C = \sum_{i=1}^{n} \frac{V_i}{E_i} l_i \quad \text{...(2)}$$

Where n is the number of sectors.

This approach can be applied on the production sectors of the economy, viz, agriculture, industry and commerce, but not to domestic consumption of electricity.

The reasons why this approach leads to a high estimate of the cost of Loadshedding are as follows:

(i) It does not distinguish between the average and marginal productivity of the electricity input, that is, there could be some economies of scale in the use of energy.

(ii) It assumes that output lost is proportional to the extent of electricity not supplied and the firms do not make adjustments to recover at least part of the output.

As opposed to the above, an approach that yields a low estimate is one which focuses only the wage cost, on the assumption that the idle factor during outages is labor. As such, in this case

$$C_i = \frac{W_i}{E_i} l_i \text{ ……………..…………………………………………..(3)}$$

Where W_i is the wage bill.

3.2. THE ADJUSTED VALUE ADDED APPROACH

This approach postulates the marginal cost of unsupplied elasticity is different from the average cost as given in (1) above. Accordingly,

$$\frac{\partial V_i}{\partial E_i} = \beta \frac{V_i}{E_i} \qquad \beta > 0 \qquad \text{…………………………………… (4)}$$

β is estimated on the basis of the historical relationship between value added and electricity consumption. Generally, it is observed that β <1.

However, the value added approaches suffer from the defect that they do not allow for spoilage costs arising from damage to materials that takes place at the time when the outage occurs, especially if there is no prior notice.

3.3 MARGINAL COST OF UNSUPPLIED ELECTRICITY

It has been argued by Bental [1982] that by observing a firms behavior with respect to the acquisition of own generating power, the marginal cost of unsupplied electric energy may be inferred. A competitive risk-neutral firm equates, at the margin, the cost of generating a kwh on its own to the expected gain due to that kwh. This expected gain is also the expected loss from the marginal kwh which is not supplied by the utility. Therefore, the marginal cost of generating its own power may serve as an estimate of the marginal outage cost.

The cost to a firm of generating its own power consists of the two elements. The first part is the yearly capacity cost of the generator. This can be represented as follows:

K(c) = annual capital cost (depreciation + interest cost) of a generator with capacity in kva

In addition,

VC = variable cost per Kwh, consisting mainly of fuel cost

l = hours of outages

The marginal cost, MC of self-generation per Kwh is given by

$$MC = \frac{\partial K(c)}{\partial c} + vc \text{……………………………….. (5)}$$

On the assumption that the MC is constant, the total cost, TC, of Loadshedding is given by

$$TC = MC.l \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

This approach may not lead to proper estimates in the following cases:

(i) Presence of economies/ diseconomies of scale in the capital cost of generators such that $\frac{\partial K(c)}{\partial c}$ is not constant.

(ii) Imperfections in the capital market whereby firms, especially the smaller ones, are unable to borrow for acquisition of a generator.

(iii) In Pakistan previous surveys of firms, for example by the Institute of Public Policy [2009], indicated that not all units have self-generation. This implies that the marginal cost of outages is lower than the marginal cost of a generator. For such units, this method cannot, therefore be applied.

3.4. THE VALUE OF LEISURE APPROCH

M. Munasingha [1980] has proposed a novel approach for evaluating the cost of outages to residential consumers, as the value of leisure foregone. According to this approach, the principal outage cost imposed on a household is the loss of leisure during the evening hours when electricity is essential. During the day time there is sufficient slack in the execution of household activities that are interrupted by the outage, such as cooking or cleaning, to permit rescheduling of these activities without causing much inconvenience.

As such, the monetary value of this lost leisure is equal to income earning rate on the basis of consumers' labor–leisure choice. Munashinghe accordingly computes the cost per Kwh of unsupplied electricity as

$$C = \frac{y}{k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

Where y is the hourly income and k the normal level of electricity consumed per hour in the absence of outages. Therefore, the total cost of outages to residential consumer is, C, where

$$C = \frac{y}{k} . l \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7)}$$

A principal practical advantage of this method of estimating outage costs for residential consumers is that it relies on the relatively easy-to-obtain data. But for proper application of this method it is essential to have the levels of electricity consumption by households at different income levels.

Other problems with this approach include the following:

(i) It assumes that the income earner in the household has flexible working hours so that he/she can effectively exercise his/her labor-leisure choice. This may be true in the case of self-employed persons. But for wage earners who work fixed hours, the marginal value of leisure is unlikely to be equal to the income rate per hour. As such, some authors have preferred to apply this approach by assuming that the value of leisure is only a fraction of income.

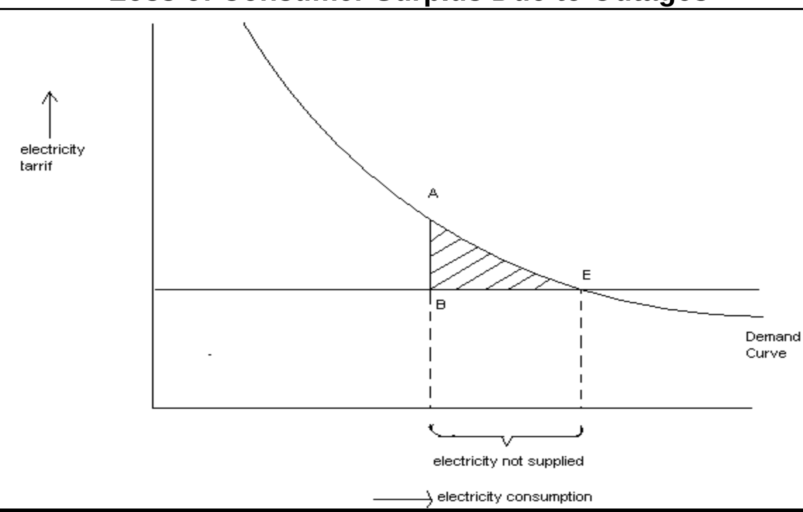
(ii) It ignores the presence of household economic activities like cottage industry or sewing/embroidery work by women, especially in lower income households. This is sometimes the case in Pakistan. Such, activities may not readily be rescheduled in the presence of outages, especially if they are of long durations. As such, in these cases the cost of outages must include the value of lost output.

(iii) Outages, especially when accompanied with voltage fluctuations, can damage home-based appliances like TV, refrigerator, air-conditioner, freezer, etc. Cost has to be incurred to repair the damage. These are equivalent to spoilage costs and should be included in the cost of loadshedding.

3.5. THE CONSUMER SURPLUS APPROACH

This is relatively popular approach and has been applied by Sanghvi [1982]. The demand curve for electricity captures the willingness to pay for the service and the consumer surplus of electricity supply is represented by the area between the demand and supply curves. The loss of consumer surplus due to supply interruptions is represented by the shaded area, **ABE,** in Figure 3.1 below.

Figure 3.1
Loss of Consumer Surplus Due to Outages



The prime magnitude required for application of this approach is the price elasticity of demand, which is not possible to measure in the presence of outages. Also, given a non-linear schedule of power tariffs, as is the case with residential consumers in Pakistan, the magnitude of the consumer surplus lost due to outages becomes difficult to quantify. Further, if AB is large then the consumer may be able to reduce the loss by investing in self-generation. This becomes more attractive the larger the amount of electricity not supplied.

3.6. THE CONTINGENT VALUATION (WTP) APPROACH

This approach involves asking consumers their willingness to pay for more reliable supplies of power. For example, the question could be as follows:

If the incidence of outages is reduced to half its present level, how much more would you be willing to pay on your monthly electricity bill?

An alternative approach is to ask the following question:

If level of outages were to double, what reduction in your monthly electricity bill would you consider to be fair?

The contingent valuation approach is prone to giving biased estimates as it is based on subjective responses. It is likely that in response to the first question the consumer understates his willingness to pay for improved service, while he may overstate the compensation that he would like to receive for deterioration in the reliability of supply.

3.7. THE SURVEY BASED APPROACH

The most comprehensive approach to quantify the cost of outages is to undertake a random survey of affected consumers. This enables explicit and direct determination of different components of outage costs including the spoilage cost, idle factor cost and adjustment cots.

However, the survey based approach is more costly than approaches which rely largely on secondary data. Also, the possibility of a bias cannot be ruled out by the respondents who may exaggerate the costs in order to attract greater attention to the problem of loadshedding.

3.8. RESULTS OF INTERNATIONAL STUDIES

The results on estimates of outage costs per kwh in studies done in other countries are presented in Table 3.1. The principal conclusions are as follows:

(i) Much of the interest in deriving the cost of outages has been in the USA, primarily in the decade of the 70s. Other countries where estimates have been made include the UK, New Zealand, Canada, Finland and Taiwan. There are some studies on developing countries like Pakistan, Egypt, Nigeria, Chile and Zimbabwe.

(ii) The focus of the studies has been mostly on the cost to residential, commercial and industrial consumers. There are few studies on agricultural consumers.

(iii) The survey-based approach has been used primarily in the cases of industrial and commercial consumers, whereas indirect proxies have been used for domestic consumers.

(iv) Among different types of consumers, the highest outages cost per kwh appears to be in the case of commercial consumers, followed by industrial consumers. These costs emerge as relatively small for domestic and agricultural consumers.

(v) Within a consumer category, like industrial or commercial consumers, the highest cost estimate is yielded by the survey-based approach. For the residential sector, the largest cost is produced by the value of leisure approach. As highlighted earlier, this probably represents a significant overstatement.

(vi) Outage costs per kwh are generally a large multiple of the power tariff in public supply.

Table 3.1
Cost of Outages per kwh to Different Types of Consumers in Various Countries

Approach	Authors	Average outage cost per kwh ($)
RESIDENTIAL SECTOR		
Value of Leisure	Sheppard[1965:UK]; Lundberg[1970:UK]; Yaborf of [1980:USA]; Munasinghe [1977:Brazil]; Turner [1977:New Zealand]	2.10
WTP Survey	Lundberg[1970:Sweden]; Ontario Hydro [1977]; Finnish Power Producers Council [1978]; Yaborff[1980:USA]; Faucett [1979:USA]; Systems[1980,USA]	1.04
Standby generator cost	Sanghvi[1980,USA]	2.25
Consumer Surplus Loss	Sanghvi[1980,USA]	0.58
Estimated by Survey	Balducci[2002,USA]	0.75
INDUSTRIAL SECTOR		
Estimated by Survey	Swedish Electric Council [1969]; Modern Manufacturing[1969:USA]; Gannon/IEEE[1971:USA]; IEEE[1973:USA]; UNIPEDE [1970 Sweden]; Jackson& Salvage[1974:UK]; Ontario Hydro [1977]; Sanghvi[1980,USA]; Balducci[2002,USA];	4.25
Cost of Wages Lost	Sheppard[1965:UK]; Turner [1977 New Zealand]	2.21
Value Added Lost	Lundberg[1970:UK]; Taiwan Power Co[1975] Yaborf[1980:USA];	3.46
COMMERCIAL SECTOR		
Cost of Wages Lost	Sheppard[1965:UK]; Turner [1977 New Zealand] Yaborf[1980:USA];	3.30
Estimated by Survey	Lundberg[1970:Sweden];Patton[1975:USA]; Congressional Research Service [1979:USA]; Ontario Hydro [1978]; Finnish Power Producers Council [1979]; Balducci[2002,USA]	6.65
AGRICULTURE		
Estimated by Survey	Balducci[2002,USA]	0.65

At this stage, some conclusions may tentatively be drawn about the cost of Loadshedding in Pakistan from the above findings. First, these costs are likely to be limited by the share (47%) of domestic consumers in electricity consumption, where outage costs appear to be low. Second, approaches based on secondary data may yield lower magnitude of costs as opposed to primary data obtained from a survey of units.

CHAPTER 4
EARLIER ESTIMATES OF COSTS OF LOADSHEDDING IN PAKISTAN

The previous Chapter has highlighted the various approaches that can be used for deriving the cost of outages. This Chapter summarizes the results of various studies in Pakistan undertaken earlier to quantify the costs of load shedding.

4.1 THE PASHA, GHAUS AND MALIK STUDY

This study was undertaken in 1987 when load shedding first emerged as a problem, with support from USAID. It was a pioneering study undertaken in the context of a developing country and was subsequently published in the prestigious international journal, **Energy Economics**. This study is extensively quoted in the literature.

The study involved an in-depth survey of 843 units, randomly selected from different locations in Pakistan. Table 4.1 reveals the distribution of costs due to power outages, with differentiation between planned and unplanned outages.

Table 4.1
Break-up of Outage Costs

(% of units)

	Planned Outages	Unplanned Outages
Direct Cost	**87.8**	**89.1**
Spoilage Cost	54.8	54.7
Idle Factor Cost	33.0	34.4
Indirect Cost	**12.6**	**10.1**
Labor Related Cost[a]	3.2	5.3
Capital Related Cost[b]	8.4	5.8
Timing Related Cost[c]	1.0	0.0
Total Cost	**100.0**	**100.0**

[a] Cost of additional overtime or shifts
[b] Cost of generators or more intensive operation of machinery
[c] Cost of changes in shift timings or working days

Bulk of the costs was in the form of direct costs, including spoilage and idle factor costs. Adjustment (indirect) costs were limited, especially since, at the time of the survey, only 12% of the units had acquired self-generation capacity[4] . Other adjustments included overtime work by

[4] The marginal cost of self-generation was 250% of the power tariff

26% of units, working additional shifts by 8% and changing shift timings or working days by 2% respectively.

The estimated cost of loadshedding per kwh in different industries is given in Table 4.2 A number of key conclusions emerge from the Table. First, the outage costs due to unplanned outages were substantially higher by 75 percent in relation to costs associated with planned outages. Second, outage costs in continuous process industries were five to six times higher than in batch-making industries. Third, there is substantial variation in outage costs among industries, ranging from a minimum of 24 cents to 185 cents per kwh.

Table 4.2
Cost of Planned and Unplanned Outages per Kwh in different Industries

		Cents/KWH
	Planned Outages	**Unplanned Outages**
Industry Group		
Food, Beverages and Tobacco	54	164
Textiles	23	29
Wearing Apparel &Footwear	62	70
Chemicals	57	102
Wood and Paper	69	178
Non-Metallic Mineral Products	23	24
Metal and Metal Products	35	72
Machinery and Equipment	139	185
Other Industries	29	54
By Process		
Batch-making	20	38
Continuous Process	119	200
Total	**36**	**63**

Overall, it appears that in 1987 the average cost of outages to industrial consumers in Pakistan was approximately 50 cents per kwh. This is significantly lower than estimates for developed countries, highlighted in Table 3.1.

Based on the same data set, the authors published another paper on the differentiated impact (by size of unit in terms of employment) of load shedding. The survey revealed that the incidence of load shedding was higher for small units (employing up to 10 workers) at 230 hours annually as compared to 179 hours for medium sized units (employing more than 10 workers up to 50 workers) and 103 hours in the case of large units (employing more than 50 workers).

The pattern of adjustment also appeared to vary by size of firm, as shown in Table 4.3. Only 2% of small units had acquired a generator as compared to 22 percent in the case of large units. Similarly, while 18% of small units increased overtime work, over 31% of large firms opted for this form of response to loadshedding. The extent of recovery of lost output was the highest at 63% by large units.

Table 4.3
Pattern of Adjustment by Size of Unit

(%)

	Small	**Medium**	**Large**
Utilising Capacity more Intensively	26	29	22
Working Overtime	18	30	31
Working Additional Shifts	8	7	6
Changing Production Techniques	21	19	11
Buying Generators	6	9	22
Changing Shift Timings	2	2	0
Changing Working Days	2	3	1
Making Some Adjustment	**69**	**79**	**87**
Extent of Recovery of Output	**35**	**63**	**40**

Overall, it is clear that power loadshedding had a larger adverse impact on small and medium-sized units as compared to large units. This is attributable not only to the higher incidence of outages but also to the relative lack of flexibility to make adjustments with small units.

The study also derived the impact of the economy-wide multiplier, that is, the second round consequences of outages in terms of impact on aggregate demand. The multiplier had a magnitude of 1.37, imply that the economy-wide impact was 37% higher than the cost incurred directly by production units.

4.2 THE IPP STUDY

This study was undertaken in 2009, when concerns started being voiced about the alarming rise in loadshedding in the country, especially in Punjab. The research study was carried out by the same team, Pasha and Ghaus, which had carried out the 1987 study. However, the sample was substantially lower, due to budget constraints, at 65 and limited only to large–scale industrial units in the major cities of Punjab.

The survey revealed that the level of load shedding were substantially higher at over five times the level prevailing in the mid-80s. It was estimated at an average of 3.8 hours per day, with the peak level being observed during the months of December to March. The sample firms reported that over 20% of the time that they could have been in production was lost due to loadshedding.

The incidence of adjustments was greater than in 1987 due to the high level of loadshedding. 75% of the firms were engaged in self-generation; 18% worked more overtime and 15% worked additional shifts.

The value added loss was considerably larger for units without self-generation. The overall cost of loadshedding to industry was estimated at Rs 157 billion equivalent to 9% of national value added. Inclusive of the multiplier of effect the cost was Rs 230 billion.

The implied outage cost per kwh was estimated at approximately at 50 cents. This is close to the 1987 estimate, despite higher incidence of load shedding and more frequent adjustments.

4.3 THE PIDE STUDY

This study was undertaken by R. Siddiqui, H.H.Jalil, M.Nasir, W.S. Malik and M. Khalid of PIDE and published in 2011. A survey was undertaken of 339 firms in four cities of Punjab. It excluded small units (employing 10 or less workers).

The study estimated that the sample units on average lost 3.3 hours per day. This is close to the 2009 estimate by IPP. Almost 25% of the firms lost more than 5 hours a day.

In terms of adjustments, this survey also revealed a high frequency, with 76% of the units having opted for stand-by generators. 69% of sample firms reported delays in delivery of orders. The methodology used for quantifying the cost of loadshedding consisted primarily of deriving the idle factor cost of labour only and excluding spoilage or other adjustment costs. As such, the cost is understated. The cost is estimated on the basis of assumed length of shift at 8, 10, or 12 hours.

The resulting loss in value of production is estimated at Rs 400 billion for Punjab with an 8 hour shift and Rs 267 billion with 12 hour shift. Conversion to value added and blowing up the sample for Pakistan as a whole, the estimate of cost of loadshedding is Rs 176 billion for the large-scale manufacturing sector, equivalent to 12% of the total national value added by the sector. As such, this estimate is somewhat higher than that by IPP in 2009.

4.4 CONCLUSIONS

The above studies enable the following conclusions:

i. Levels of loadshedding have risen to unprecedented levels in recent years and on average firms have experienced outages between 20 to 25% of their working hours.

ii. Adjustments of various types have been made by a high proportion of firms, including investment in self-generation by over three-fourths of the units.

iii. The costs of loadshedding to industry have reached a high level, equivalent to 10% or more of national sectoral value added or almost 2% of the GDP. These losses have been accompanied by significant declines in profitability, employment and exports.

iv. The average cost of outages to industry is about 50 cents per kwh. This is high in relation to the existing level of power tariffs. But it is low by international standards.

CHAPTER 5
COSTS OF LOADSHEDDING (FROM SECONDARY DATA)

Chapter 3 has described the various approaches that have been developed for estimation of the economic cost of loadshedding. Chapter 4 then has highlighted the results of earlier studies on quantification of the costs loadshedding in Pakistan by application of some of these approaches. This chapter extends the analyses by applying more approaches, especially those that can be implemented with secondary data. In addition, an attempt is made to up-date the estimates of the cost of loadshedding upto 2010-11.

5.1 THE SIMPLE VALUE ADDED APPROACH

The estimated value added per kwh (at constant prices of 1999-2000) is presented for different years in Table 5.1 As the electricity-intensity of the economy has been rising, this ratio has shown a downward trend. For the economy as whole, the value added per kwh has declined by almost 2% annually over the last forty years, such that the magnitude in 2010-11 is less than half of the value in 1971-72. It is interesting to note that, contrary to the overall trend, the value added per kwh in industry has risen, albeit slowly. The implication is that the industrial structure of Pakistan is moving in the direction of less energy-intensity, in contrast to the trend observed in most developing countries.

The table also demonstrates, however, that industry is more electricity-intensive than agriculture and commerce. Accordingly, the simple value added approach will imply that the outage cost per kwh is the highest in commerce/services, followed by agriculture and the lowest in industry.
The value added per kwh of 2000-01 is used for this analysis. During this year there was significant excess capacity in the power sector and there was hardly any loadshedding. This is projected up to 2010-11 on the basis of the growth rate between 1971-72 and 2000-01. The approach produces very high estimates of outage cost per kwh of $ 2.13 in the case of industry, $4.44 in agriculture and as much as $ 20.65 in commerce/services. This compares with the outage cost per kwh of $ 0.50 in earlier studies for Pakistan. Given the estimates of cost per kwh and the quantity of electricity not supplied, based on the incidence of loadshedding at 20% of working hours, the total cost of outages works out to a whopping Rs 1.6 trillion. This estimate is beyond reasonable expectations and is rejected outright.

5.2 THE ADJUSTED VALUE ADDED APPROACH

This approach has been described in the Section 3.2 of Chapter 3. The magnitude of β is estimated by econometric analysis on historical data for the period when there were no significant outages (see Technical Annex 1).

Table 5.1
Cost of Outages with the Adjusted Value Added Approach

	β	**Outage cost per kwh (Rs)**	**Quantity of electricity Not Supplied**	**Cost of Outages (Rs in Billion)**
Sector				
	With 20 % time loss			
Agriculture	0.050	18 (0.22) *	2243	42 (0.5) **
Industry	0.126	22.8 (0.27)	5302	121 (1.4)
Commerce/Services	0.062	108.8 (1.28)	2759	300 (3.5)
Total			**10304**	**463** **(5.4)**

* in US $
** in billion US $

With the adjusted approach the total cost of loadshedding falls very sharply to Rs 463 billion or $ 5.4 billion. However, these estimates are at the other extreme and look too low although they are consistent with the international evidence that cost per kwh is highest in commerce, followed by industry and agriculture. For example, the outage cost per kwh to industry is derived as 27 cents, compared to 50 cents in other earlier studies. As such, this approach does not appear also to be giving credible estimates.

A new variant of the value added approach has been developed for this study for quantification of outage costs which focuses on the relationship between development of infrastructure and economic growth. The former includes electricity generation. The relationship is estimated of GDP per capita growth rate with through on OLS regression the following explanatory variables:

Agricultural Growth Rate	=	AGR
Private Investment as % of GDP	=	PRI
Growth Rate of Electricity Generation per Capita	=	EGE
Growth Rate of Water Availability (in agriculture)	=	WAV

The results of the econometric analysis are presented in the Technical Annex 2. It appears that a 1% increase in electricity generation per capita leads to a 0.167% increase in per capita GDP. The next step in the analysis is to compare the actual growth rate of electricity generation per capita from 2007-08 with the growth rate historically during the period when there was minimal loadshedding. Given the coefficient of 0.167 the impact on the GDP per capita of a slowdown in the process of electricity generation, which has led to outages, can be determined. The divergence in growth rates is presented in Table 5.2.

Table 5.2
Projected GDP (at factor cost) in the Absence of Loadshedding compared to Actual GDP

					(Rs in Billion)			
	Actual per Capita Growth Rate of Electricity Generation (%)	**Historical Per Capita Growth Rate of Electricity Generation (%)**	**Difference (%)**	**Actual per Capita GDP growth rate (%)**	**Projected GDP per capita growth rate (%)**	**Actual GDP at current prices**	**Projected GDP at current prices**	**Cost of outages**
2007-08	-5.0	4.0	-9.0	1.6	3.1	9922	10067	135
2008-09	-6.1	4.0	-10.1	-0.4	1.3	12110	12490	380
2009-10	1.9	4.0	-2.1	1.0	1.4	14034	14471	437
2010-11	-3.0	4.0	-7.0	0.9	2.1	17093	17910	817

The difference in the projected and actual GDP is the economic cost of loadshedding. It has risen exponentially according to this approach from Rs 135 billion in 2007-08 to Rs 817 billion ($ 9.6 billion) by 2010-11. It is likely that by 2011-12 the economic cost of loadshedding to the national economy has exceeded **Rs ONE TRILLION.** This is approaching 5% of the GDP.

The implied outage cost per kwh across the economy in 2010-11 is Rs 79.3 or 93 cents.

5.3 THE CONSUMER SURPLUS APPROACH

Application of the consumer surplus approach requires knowledge of the price elasticity of demand. Table 5.4 presents the estimates of this elasticity for a number of developing countries. The short-run elasticity is taken for the analysis. It appears that the elasticity is generally low, especially in countries like Turkey, Israel, South Africa, etc. The estimate of -0.13 by Jamil and Ahmed [2010] for Pakistan is used for the analysis.

The other assumption that has to be made relates to the demand that would have been observed in the absence of outage at the existing power tariff. As highlighted in Chapter **4,** consumers have been exposed to loadshedding for 20 to 25 % of their working hours. As such, it is assumed that unconstrained demand would have been at least 25% higher in comparison to the observed level.

Table 5.3
Price Elasticity of Demand for Electricity (All Consumers Combined) in Different Studies

	Author	Country	Price Elasticity (short-run)
1	Al Faris [2002]	GCC Country	-0.11
2	Bose & Shula [1999]	India	-0.34
3	Narayan [2007]	Seven Countries	-0.06
4	Zchariadis and Pashaurtidou [2006]	Cyprus	-0.02
5	Lin [2003]	China	0.18
6	Erkan [2007]	Turkey	-0.04
7	Beensock [1999]	Israel	-0.01
8	Ziramba [2008]	South Africa	-0.02
9	Jamil and Ahmed [2010]	Pakistan	-0.13

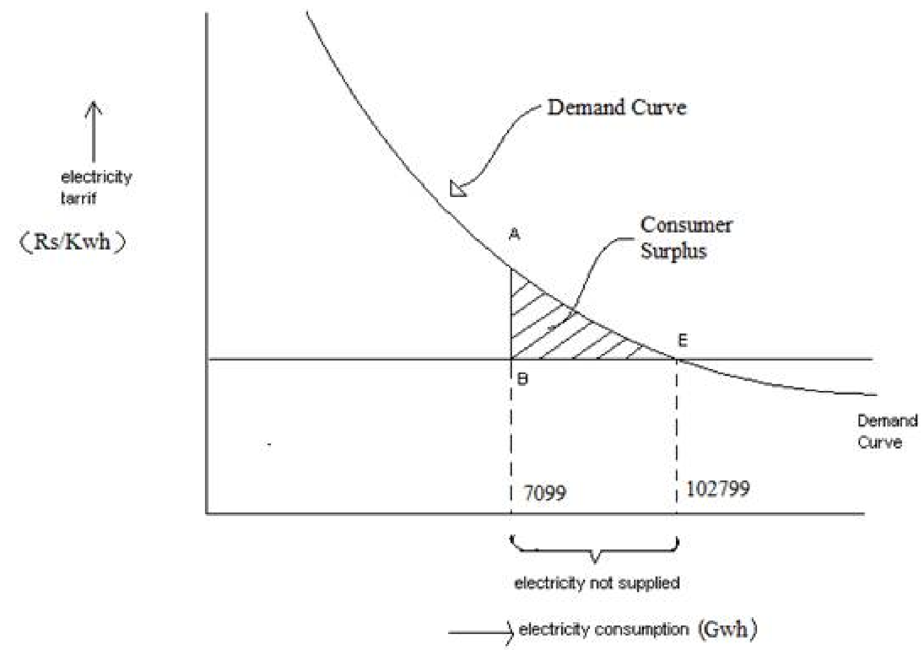
The existing effective average tariff for all consumers combined is about Rs 9 per kwh. Inclusive of the GST, withholding income tax and FAC raises it to almost Rs 13 per kwh. This is the price used for the analysis.

The consumer surplus corresponds to the shaded area in Fig 5.1.

The methodology for estimating the consumer surplus is given in Technical Annex-III.

The estimated magnitude of the consumer surplus is Rs 837 billion ($ 9.8 billion) in 2010-11. This is very close to the cost of loadshedding derived from a variant of the value added approach of Rs 817 billion ($ 9.6 billion). Therefore, secondary data based approaches to quantification of economic cost of loadshedding yield an estimate of above Rs 800 billion ($ 9.4 billion) in 2010-11 and it is likely that this cost has exceeded Rs **1 Trillion** ($ 11.1 billion) by 2011-12.

Figure 5.1
Consumer Surplus from Electricity Consumption



TECHNICAL ANNEXURE-I

Econometric analysis has been undertaken to determine by sector the relationship between electricity consumption and value added:

Agriculture

AGVAL = Agricultural value added (at constant prices)

AGELC= Electricity consumption in agriculture

Results of the OLS regression are as follows:

$$\text{Ln(AGVAL)} = \underset{(1.84)^{**}}{0.601} + \underset{(1.876)^{**}}{0.05\text{Ln(AGELC)}} + \underset{(23.46)^{*}}{0.927\text{Ln}(\text{AGVAL}_{-1})}$$

$R^2 = 0.994$, D-W = 2.68, Degrees of Freedom= 37

*Significant at 5 per cent level ** Significant at 10 per cent level

Industry

INVAL = Industrial value added (at constant prices)

INELC = Electricity consumption in industry

Results of the OLS regression are as follows:

$$\text{Ln(INVAL)} = \underset{(3.434)^{*}}{0.702} + \underset{(2.374)^{*}}{0.126\ \text{Ln(INELC)}} + \underset{(16.964)^{*}}{0.864\ \text{Ln}(\text{INVAL}_{-1})}$$

$R^2 = 0.998$, D-W = 1.468, Degrees of Freedom= 37

*significant at 5 per cent level

Services

SEVAL = Services value added (at constant prices)

SEELC = Electricity consumption by services

Results of the OLS regression are as follows:

$$\text{LN(SEVAL)} = \underset{(2.969)^{*}}{0.844} + \underset{(2.038)^{*}}{0.062\ \text{LN(SEELC)}} + \underset{(25.132)^{*}}{0.910\ \text{LN}(\text{SEVAL}_{-1})}$$

$R^2 = 0.998$, D-W = 2.027, Degrees of Freedom = 37

*significant at 5 per cent level

TECHNICAL ANNEXURE-II

Econometric analysis has been undertaken to determine the relationship between GDP growth per capita and growth of infrastructure (including power generation) and basic services (like education)

The following variables are designated:

GGDP = Growth rate of real GDP per capita
GAG = growth rate of agriculture
r = nominal interest rate
GSCH = growth rate of mean years of schooling
GWAT = growth rate of water availability (in agriculture)
Results of the OLS regression are as follows:

$$\underset{(2.447)^*}{GGDP = 2.946} \quad + \underset{(6.357)^*}{0.32\ GAG} \quad - \underset{(-2.746)^*}{0.252r} \quad \underset{(2.530)^*}{+0.304\ GSCH} \quad \underset{(5.193)^*}{+0.167\ GELE}$$

$$\underset{(4.592)^*}{+0.325\ GWAT}$$

R^2 = 0.726, D-W = 2.646, Degrees of freedom= 36

*Significant at 5 per cent level

The analysis is undertaken for the period, 1975-76 to 2010-11.

The Wu-Hausman test was performed to test for endogeniety.

The equation passed the test.

It appears that a 1 per cent increase in electricity generation per capita raises the GDP per capita growth rate by 0.167 per cent.

TECHNICAL ANNEXURE III
ANALYSIS OF WILLINGNESS TO PAY

(Aggregate)

The demand function given by the function

$q = Ap^{-\propto} \Rightarrow$ p = $(\frac{A}{q})^{\frac{1}{\propto}}$

Suppose that in the absence of outages the demand (unconstrained) would have been 25% higher

Therefore,

$$102799 = A(13.00)^{-0.13}$$

Where the price elasticity of demand is taken as -0.13, as derived by Jamil and Ahmed [2010]

From (2)

$$A = 102799(13.00)^{0.13} = 102799(1.396) = 143507$$

When $q = 77099$

$$p^{0.13} = \frac{143507}{77099} = 119.00$$

Area under the demand curve is given by

Area = $\int_{77099}^{102799} (\frac{A}{q})^{7.692}\, dq$

Area = $4.642 \times 10^{39} \int_{77099}^{102799} q^{-7.962}\, dq$

Area = $\frac{4.642\times10^{39}}{6.692}[-(77099)^{-6.692} + (102799)^{-6.692}]$

Area = $-0.694 \times 10^{39}[-1.976 \times 10^{-33} + 2.882 \times 10^{-34}]$

Area = $-0.694 \times 10^{6}[-1.976 + 0.288]$

Area = $0.694 \times 10^{6} \times 1.688 = 1.171 \times 10^{6}$

Consumer Surplus = $1.171 \times 10^{6} - 0.334 \times 10^{6}$

Therefore, Consumer Surplus = $.837 \times 10^{12} Rs$ because consumption is in Gwh.

As such, CS = Rs 837 billion.

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